A Computational Model Improvement for the BNCT Thermal Neutron Beam at the University of Missouri

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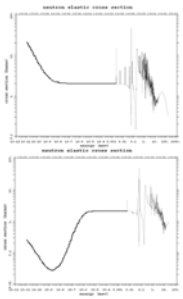
Motivation

- Previous computational models of the MURR system used the BUGLE-80 energy group structure, a common multi-group arrangement for epithermal neutron beams.
- The 2 thermal groups provided by BUGLE-80 are not detailed enough to accurately model the single crystal neutron filters found in the thermal neutron beamline.
- More thermal groups are needed for a more accurate model of the neutron interactions with the single crystals. This will yield a better model of the irradiating beam spectrum for more detailed computational dosimetry results.
- A better multi-group model will give a better source from discrete ordinates calculations for an MCNP model of the beamline.



Top: Amorphous silicon elastic scattering cross section.

Bottom: Single crystal elastic scattering cross section.

Computational Methods

- MCNP: Monte Carlo N-Particle Transport Code
- DORT: Discrete Ordinates Radiation Transport Code
- COMBINE 7.1: A Portable ENDF/B-VII.0 Based Neutron Spectrum and Cross-Section Generation Program

COMBINE 7.1 → (ANISN Free Format Microscopic Cross Sections) → GIP → (Mixed Binary Macroscopic Cross Sections) → DORT → (Neutron Information)

Code and Library Verification

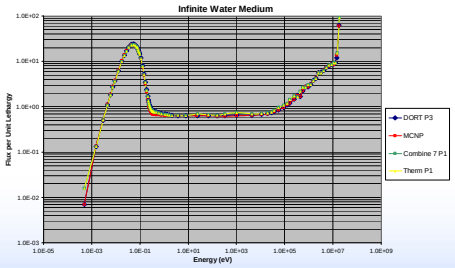
- Needed to check the mathematical accuracy of the codes and generated multi-group libraries for this application. MCNP5 is used as the continuous energy reference point for the verification calculations along with analytical solutions.
- Microscopic cross sections for each of the model material constituents are generated using COMBINE 7.1 over a 59-group energy structure. Above 0.414eV, the energy structure closely matches the BUGLE-80 structure. Below 0.414eV there are 20 thermal groups.
- Three media were tested in idealized geometries: water, carbon, Lucite.

Infinite Water Medium Results

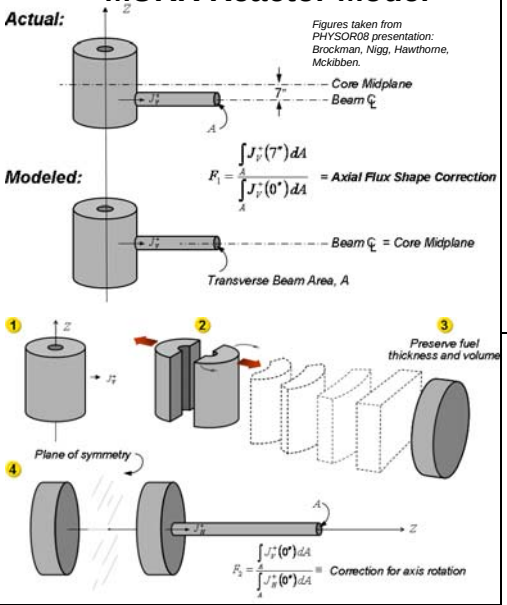
•The analytical Therm solutions along with the COMBINE 7.1 results use a P1 Legendre scattering expansion.

•The DORT results use a P3 Legendre scattering expansion and a single spatial mesh point in a 1x1x1cm reflected box to simulate an infinite medium.

•s8 quadrature



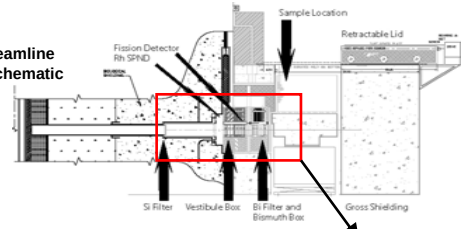
MURR Reactor Model



Figures taken from PHYSOR08 presentation: Brockman, Nigg, Hawthorne, Mckibben.

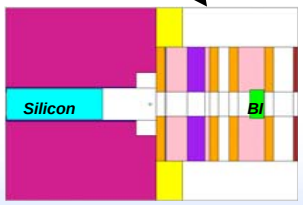
MURR Beamline Model

Beamline Schematic



•MCNP model (right image) created with identical cylindrical geometry to DORT beamline model.

•Special MCNP cross section sets from KENDF were used to model the single crystal filters



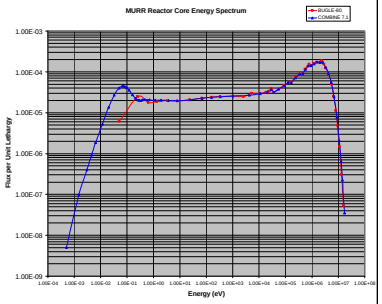
MURR Reactor Model Results

•The BUGLE-80 models do not have thermal up-scatter included in the neutron cross section data.

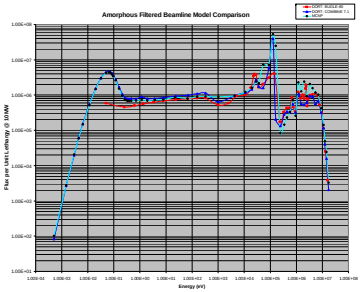
•The reactor and beamline models use u315 quadrature due to the forward biased nature of transport down the beam tube.

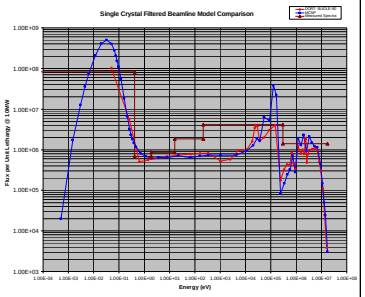
•BUGLE-80 uses infinite dilute resonance calculations for all isotopes in the model.

•The COMBINE 7.1 library uses the homogenized densities for all reactor fuel cell constituents and averages cross sections for all materials outside of the core over the core spectrum.



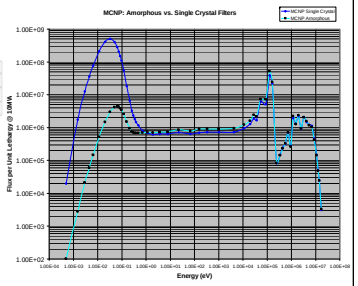
MURR Beamline Model Results





Single Crystal Filtered Beam Thermal Flux			
Data Source	Flux@10MW	% Difference	Uncertainty (1σ)
Laboratory Measurement	8.80E+08 n/cm²s	**********	6%
BUGLE-80 DORT Model	9.62E+08 n/cm²s	9.30%	10%
COMBINE 7.1 DORT/MCNP Model	9.20E+08 n/cm²s	4.55%	4.06%

Table: Thermal flux results from the previous single crystal filtered DORT beam model and the new COMBINE 7.1 DORT/MCNP model normalized to the full rated reactor power of 10MW and compared to laboratory thermal flux measurements of the single crystal filtered beam.



Acknowledgements

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